SCHOOL OF CIVIL ENGINEERING

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THE INFLUENCE OF RETARDING ADMIXTURES ON THE DRYING SHRINKAGE OF CONCRETE

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Final Report

THE INFLUENCE OF RETARDING ADMIXTURES ON THE DRYING SHRINKAGE OF CONCRETE

TO:	J. F. McLaughlin, Director Joint Highway Research Project	August 28, 1974
		Project: C-36-47L
FROM:	H. L. Michael, Associate Director Joint Highway Research Project	File: 4-6-12

Attached is an Interim Report "The Influence of Retarding Admixtures on the Drying Shrinkage of Concrete". It has been authored by W. L. Dolch and C. F. Scholer, the principal investigators on the study.

This report concerns the effects of five retarding admixtures on shrinkage of concrete. The conclusions are that the influence on shrinkage of the retarders tested is not significant to engineering considerations.

This is the final interim report on this study and will be followed shortly by a Final Summary Report of the entire study.

The Report is presented for acceptance as partial fulfillment of the objectives of the study. It will be forwarded to ISHC and FHWA for similar acceptance following their review and comment.

Respectfully submitted,

Harold L. Michael

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Associate Director

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Interim Report

THE INFLUENCE OF RETARDING ADMIXTURES ON THE DRYING SHRINKAGE OF CONCRETE

by

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and

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Joint Highway Research Project

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and the

U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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Conducted in cooperation with the U.S. Dept. of Transportation, Federal Highway Administration. Research Study titled"Effect of Retarders on Volume Changes in Portland Cement".

16. Abstract

Concretes were made containing six bags of cement per cubic y yard, five retarding admixtures plus control, and at slumps of two or six inches. The admixtures were a lignosulfonate, a hydroxyacid, and a carbohydrate proprietary materials and glycolic acid and sucrose.

The hardened concretes were dried at 73F and 50 percent relative humidity. Shrinkage was determined at times from 7 days to 6 months.

There were no sytematic differences in the maxium shrinkage values except that those for concrete containing the hydroxyacid retarder were slightly lower than the others. The shrinkage-log time date seem, in most cases, to be reasonably well represented by two straight lines breaking at the 28-day value.

It is concluded that the influence of these retarders on shrinkage of concrete is not significant to engineering considerations.

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Highlight Summary

The Influence of Retarding Admixtures on the Drying Shrinkage of Concrete

The aim was to determine if the use of set-retarding admixtures in concrete affects the drying shrinkage of hardened concrete. This is a subject on which conflicting evidence exists. It is important because increased drying shrinkage could lead to increased cracking, especially under those conditions of heat and wind that promote drying.

Five admixtures were used - three proprietary and two reagent chemicals. They were a lignosulfonate, a hydroxyacid, and a carbohydrate type along with sugar and glycolic acid. The concretes were formulated to simulate highway concrete, and the specimens were dried in the standard manner at 50 percent humidity. The shrinkage was measured up to 6 months of drying.

Little difference was found among any of the materials tested, and the differences that did exist were probably not important in terms of engineering design and practice. The logical conclusion from these results is that no extra precautions need be taken in design or construction, with respect to shrinkage of the hardened concrete, when the admixtures tested here are used in the concrete.

The Influence of Retarding Admixtures on the Drying Shrinkage of Concrete

Introduction

This part of the study was an effort to obtain numerical data on the drying shrinkage of concrete containing set-retarding admixtures. The aim was to see if the presence of admixtures is important in this regard, if significant differences exist among various admixtures, and to obtain data that might be significant in design.

There are little reliable results from past work on the influence of admixtures on the drying shrinkage of concrete. Mielenz (1) has reviewed the subject. He emphasized the difficulty in translating the results of accelerated tests to other conditions of specimen or exposure. He outlined the somewhat contradictory results of other investigators and pointed out that the differences in drying shrinkage that have been found have usually been small.

The present knowledge (or lack of it) is summarized in the ACI Guide (2) by stating "Usually the difference is not great and sometimes less than the testing errors."

The reasons for any differences that exist among various admixtures in their influence on the shrinkage of concrete lie, at least partly, in the influence they have on the water content, the cement content, and the degree of hydration of the cement, since the cement gel content of the concrete is a primary factor controlling its shrinkage (3).

Materials

The concretes used were intended to be typical of those used, either deliberately or inadvertently, in highway construction. The cement was a Type I with no unusual chemical or physical characteristics. The coarse aggregate was a local gravel; the fine aggregate was a sand from the same deposit.

The cement factor was a nominal six bags per cubic yard of concrete. Water contents were adjusted by trial and error to give either of two slump levels - about two inches, referred to as "low" slump, or about six inches, referred to as "high" slump. Air contents were 3-5 percent, obtained by the use of an air-entraining admixture.

A typical mix design was:

Coarse aggregate -	
3/4 - 1/2	11.0 lb.
1/2 - 3/8	17.8 lb.
3/8 - No. 4	15.5 lb.
Total	44.3 lb.
Fine aggregate -	
Retained on No. 16	15.2 lb.
Passing No. 16	22.9 lb.
Total	38.1 lb.
Cement	16.2 lb.
Water	8.3 lb.

plus suitable amounts of air-entraining agent and retarder.

Five retarding admixtures were used. Three were commonly-available commercial materials, a lignosulfonate (L), a hydroxyacid (A), and a carbohydrate type (C), all of which met the requirements of ASTM C 494, Type D. Reagent-grade glycolic acid (G) and sucrose (S) were also used.

Experimental Work

All ingredients of the concrete were conditioned to either room temperature or to a lower temperature, about 55F in a cold room. The aggregates were oven-dry. Mixing was in a pan mixer, aggregates first, then cement, then water containing dissolved admixtures. Retarders were added before air-entraining agent.

Slump, yield, temperature, and air content were then determined. If the properties were those desired, 3x3x10-in. prisms were then cast according to the requirements of ASTM C157, except sometimes for the different temperature.

Concrete not cast into prisms was tested for setting time by penetration resistance, essentially ASTM C403, to ensure that retarded concretes had the desired setting time of 1.5 times that of an unretarded concrete. If this was not so, the entire mix was remade with a more appropriate admixture content.

Each mixture was assigned a number. The various combinations are shown in Table 1. The mixing order was selected by a random-choice process.

The cast concrete bars were kept under moist cloths and plastic sheeting overnight at the temperature of mixing and then were demolded and each was put in a sealed plastic bag which was stored in the constant temperature and humidity room.

This room was kept at 73.4 ± 3.0F and 50 ± 4 percent relative humidity by suitable automatic controls. Air within the room was circulated by fans. Samples were stored on racks made from pipe to allow maximum

TABLE 1

Mix Numbers and Variable Combinations

Admixture	Room Temperature Low Slump	Room Temperature High Slump	Lower Temperature Low Slump	Lower Temperature High Slump
None (n)	1,17	2,18	21,22	--
Lignosulfonate (L)	3	4,12,14	26	24
Hydroxycarobxylic Acid (A)	5	6,13	--	19,25
Carbohydrate (C)	7,11,15	8,16	--	20,23
Glycolic Acid (G)	--	9,27	--	--
Sucrose (S)	--	10,28	--	--

access of ambient air to all parts of the specimens.

After one day in the plastic bags, the samples were removed, and the initial length measurement was made in a length comparator conforming to the requirements of ASTM C-490. The specimens were then replaced in the bags and kept there until the 7-day measurement, after which they were not replaced in the bags. During their residence in this room their positions on the racks were changed from time to time and no specimen was stored next to another from the same mix. Triplicate specimens from each mix were tested.

These "curing" conditions, of the sealed plastic bag, were chosen deliberately to simulate the less-than-optimum curing that highway concrete frequently receives.

The specimens were measured at 7, 14, and 28 days of age (from demolding), and after 3 and 6 months.

Data

The drying shrinkage data along with pertinent mix variables are presented in Table 2. Illustrative plots of shrinkage vs. time of exposure, for a few mixes only, are shown in Figures 1-3.

Discussion of Results

The shrinkage results in Table 2 are about the same magnitude as those obtained by other investigators under approximately the same conditions (4).

Table 2

DRYING SHRINKAGE RESULTS

Mix No.	Mix Temp.	Slump	Admix.*	Shrinkage, percent 7d	14d	28d	3mo	6mo
1	Room	Low	N	0.006	0.012	0.026	0.036	0.041
2	Room	High	N	0.001	0.012	0.025	0.037	0.045
3	Room	Low	L	0.003	0.015	0.033	0.041	0.050
4	Room	High	L	0.003	0.021	0.037	0.047	0.054
5	Room	Low	A	0.005	0.020	0.033	0.038	0.043
6	Room	High	A	0.003	0.018	0.032	0.039	0.042
7	Room	Low	C	0.006	0.027	0.038	0.046	0.054
8	Room	High	C	0.007	0.026	0.040	0.050	0.056
9	Room	High	G	0.002	0.016	0.026	0.044	0.054
10	Room	High	S	0.006	0.021	0.034	0.047	0.059
11	Room	Low	C	0.006	0.022	0.037	0.049	0.050
12	Room	High	L	0.001	0.020	0.034	0.052	0.054
13	Room	High	A	0.002	0.017	0.029	0.043	0.045
14	Room	High	L	0.003	0.025	0.037	0.051	0.050
15	Room	Low	C	0.004	---	0.038	0.053	0.050
16	Room	High	C	0.008	0.031	0.043	0.049	0.055
17	Room	Low	N	0.011	0.030	0.040	0.052	0.056
18	Room	High	N	0.010	0.026	0.036	0.049	0.054
19	Low	High	A	0.004	0.009	0.018	0.030	0.036
20	Low	High	C	0.003	0.022	0.030	0.042	0.047
21	Low	Low	N	0.019	0.030	0.036	0.052	0.062
22	Low	Low	N	0.001	0.015	0.026	0.034	0.054
23	Low	High	C	0.030	0.043	0.059	0.072	0.075
24	Low	High	L	0.002	0.020	0.035	0.046	0.054
25	Low	High	A	-0.004	0.009	0.021	0.032	0.036
26	Low	Low	L	-0.002	0.016	0.031	0.044	0.045
27	Room	High	G	0.012	0.020	0.030	0.042	0.047
28	Room	High	S	0.009	0.022	0.032	0.048	0.053

* N = No admixture, L = Lignosulfonate, A = Hydroxyacid,
C = Carbohydrate, G = Glycolic Acid, S = Sucrose

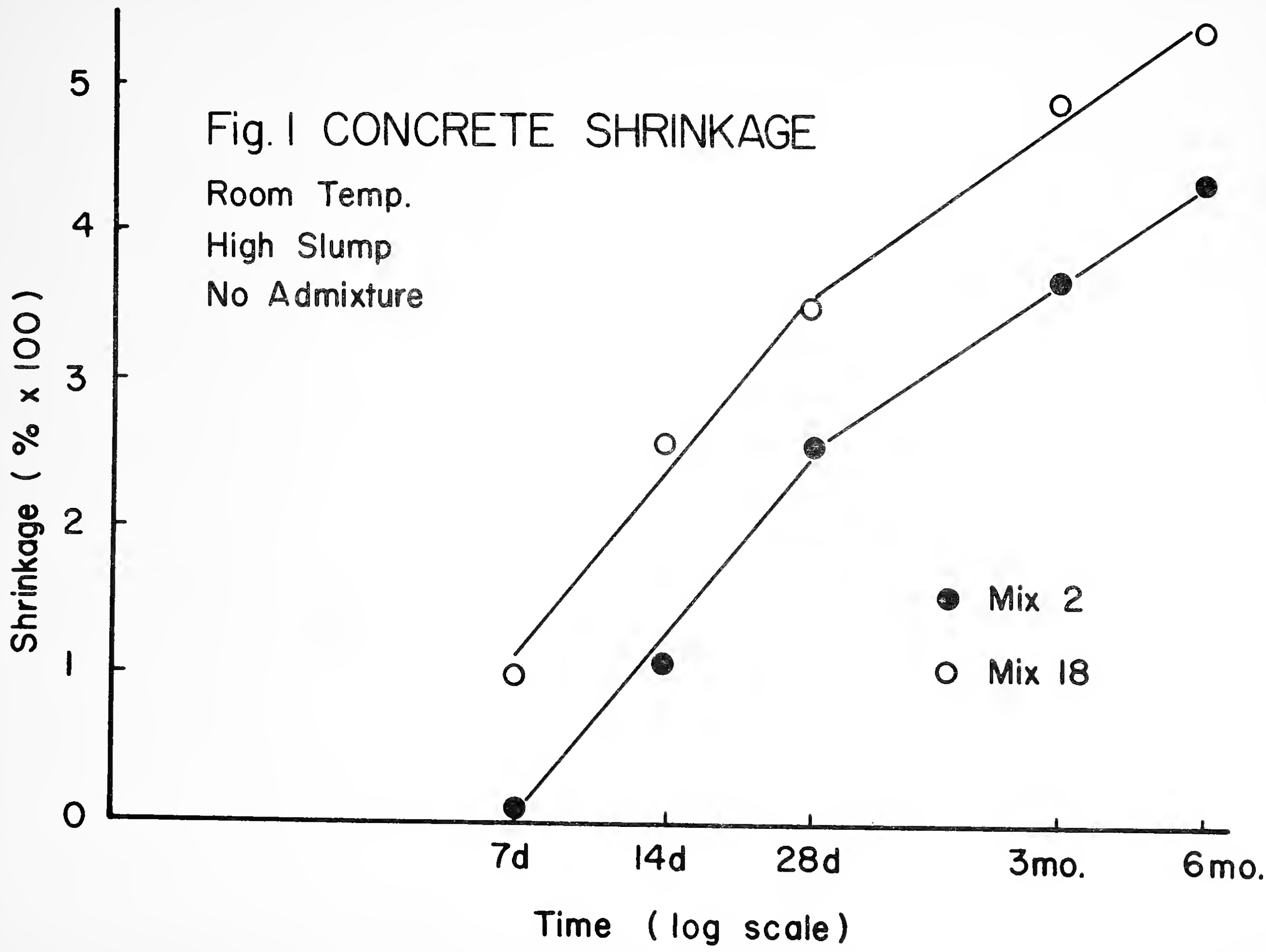

Fig. 1 CONCRETE SHRINKAGE

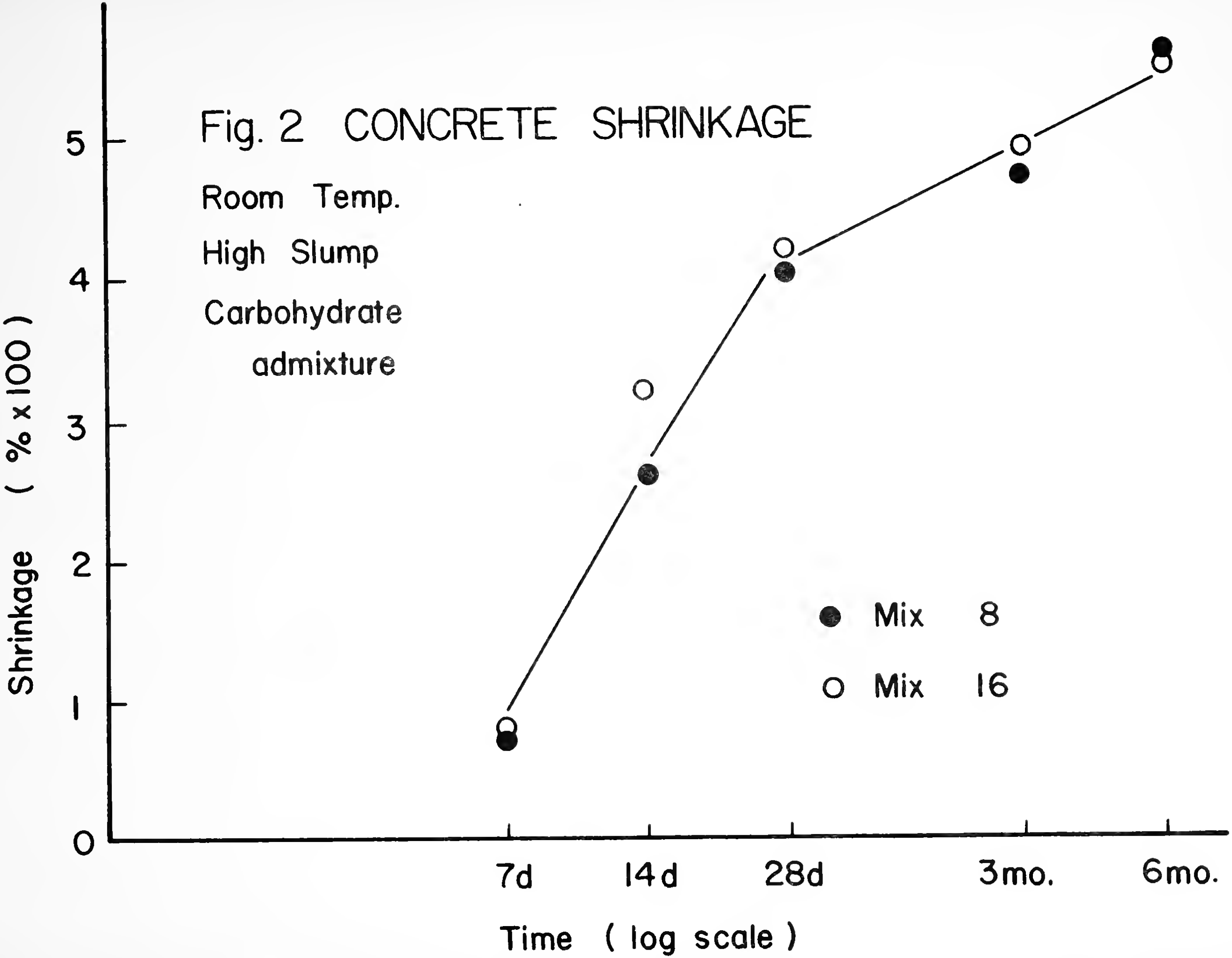

Fig. 2 CONCRETE SHRINKAGE

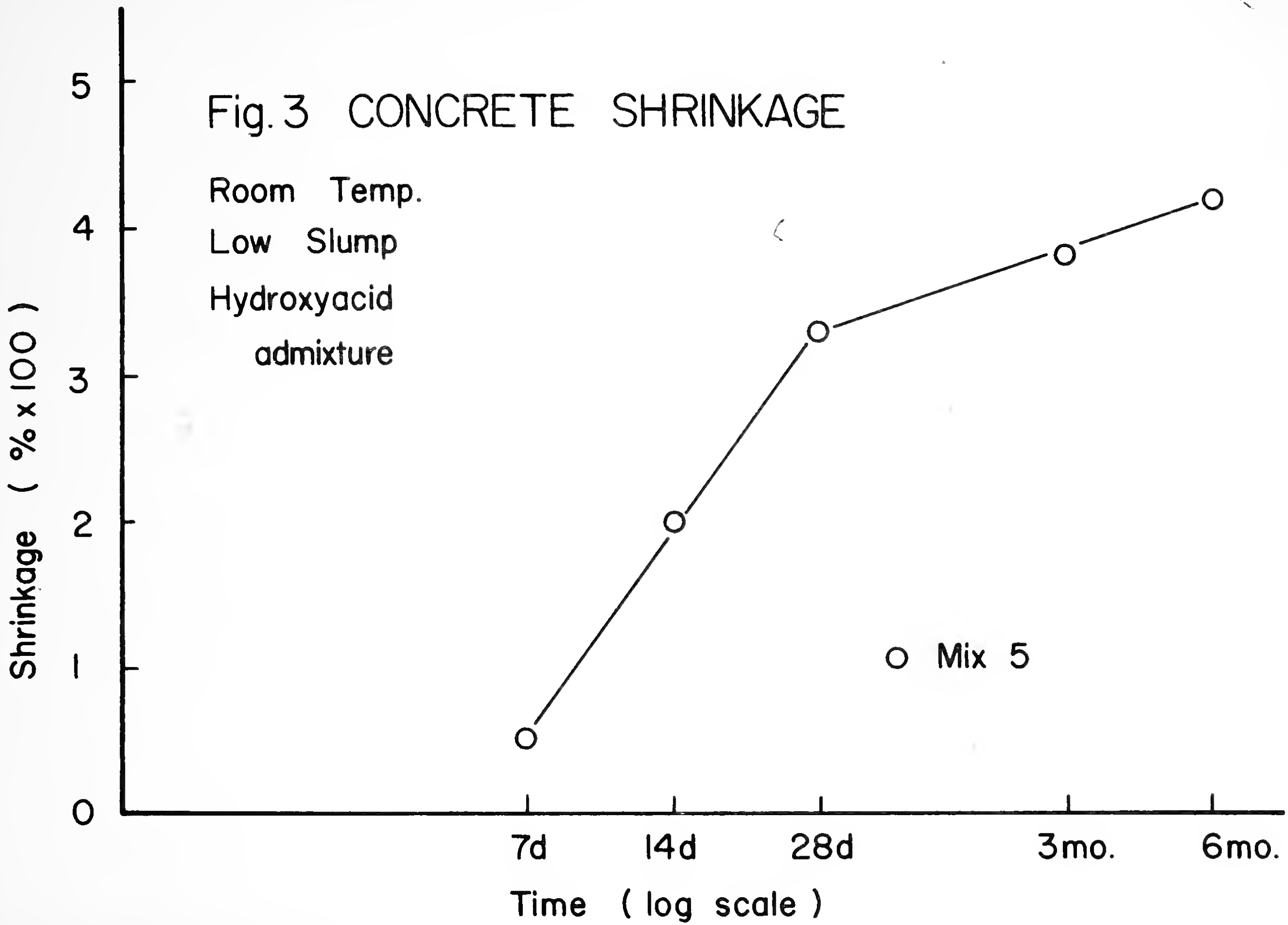

Fig. 3 CONCRETE SHRINKAGE

Preliminary statistical analysis was done in an attempt to identify significant factors and interactions. The variance of mixes within treatments with no admixture was found to be non-homogenous in relation to the mixes within other treatments and prevented further analysis of the data as a complete set. It was therefore decided to compare final values of shrinkage, i.e. that at 6 mo of age, and plots of the shrinkage vs. time, three examples of which are given in the figures.

Inspection of the Table shows that duplicate results are frequently excellent (e.g., Fig. 2, Mixes 4, 12, and 14), other times only fair (Fig. 1, Mixes 1 and 17), and poor in only one instance (Mixes 20 and 23). This agreement is considered to be a reasonable validation of the experimental techniques.

The early shrinkage values are frequently different from each other, but their low magnitude may be influenced relatively greatly by various errors. For example, the smallest dial reading corresponds to an error of 0.001 percent, and the average error is almost surely greater.

If the final value, that at 6 mo, is taken as representative of the set of experimental conditions, several tentative findings, unprovable statistically, can be pointed out. Firstly, there are no large differences in the values, If Mix 23, which probably had a gross measurement error involved, is left out of it, the largest is only about seventy percent larger than the smallest and the absolute difference is probably small in any engineering sense.

It appears that the only difference among admixtures that may be significant is the low shrinkages of the concretes containing the proprietary hydroxy acid. It can also be mentioned that these values are perhaps significantly lower than those for glycolic acid, which is of course also a hydroxyacid (hydroxyacetic acid).

There seems to be no important influence of either temperature of mixing or of slump; the latter finding is unexpected and contradicts some other data.

It will be noted that the data given in the figures can fairly well be represented by two straight lines on the semi-logarithmic plot - one for the 7, 14, and 28-day points and the other for the 28-day, 3-mo, and 6-mo points. This was not invariably so, but it seems to apply to 22 of the 28 mixes. The significance of this finding, if indeed it is valid, is unclear. The implication is that different processes may be controlling the shrinkage at early and later ages of the concrete.

The early shrinkage may be the more important because the strength is less at that time and the possibility of cracking under a given strain is greater. The slope of the shrinkage - log time curve is a measure of the rate of strain development. The slopes of the early shrinkage curves (as plotted in the figures and, therefore, in arbitrary units) are given in Table 3. The values are for the best linear curve of the first three data points.

Agreement of the slope values among replicates is generally good, even if the absolute shrinkage values are not in such good agreement

TABLE 3

Slope of Early Shrinkage - Log Time Curves

	Room Temperature		Lower Temperature	
Admixture	Low Slump	High Slump	Low Slump	High Slump
None	1.1,1.4	1.2,1.2	0.8,1.1	
Lignosulfonate	1.5	1.7,1.7,1.7	1.7	1.7
Hydroxyacid	1.4	1.5,1.5		0.7,1.2
Carbohydrate	1.7,1.7,1.7	1.7,1.7		1.3,1.4
Glycolic acid		0.9,1.2		
Sucrose		1.2,1.2		

(e.g. Fig. 1). The values for the concretes containing commercial admixtures are, for room temperature, all larger than the blanks or the mixes containing reagent admixtures. Whether these differences have any significance is conjectural.

Conclusion

Based on the materials used and the results obtained, it seems fair to conclude that the differences in drying shrinkage behavior of concretes either with or without retarding admixtures are not great enough to be of significance in engineering considerations.

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